John A. Pasko

MANHOLE COVER LIQUID LEVEL MONITORING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit under Title 35, U.S.C. § 119(e) of U.S. Provisional Patent Application Serial No. 60/395,154, entitled MANHOLE COVER LIQUID LEVEL MONITORING SYSTEM, filed on July 11, 2002.

BACKGROUND

1. Field of the Invention.

[0002] The present invention relates to liquid level sensors, and in particular to a system for wireless monitoring of liquid levels.

[0003] 2. Description of the Related Art.

[0004] Existing liquid level sensors are commonly used to detect liquid levels in tanks, reservoirs, and other closed system applications. However, such sensors do not lend themselves well to use in an open liquid handling system such as a wastewater or storm water handling system.

[0005] Some known devices use mechanical or moving parts such as mechanical switches operated by rubber diaphragms, springs, rods, floats, or balls, all of which may require adjustment and tend to wear out or malfunction over time.

[0006] Mechanical sensors may not reliably hold up to the long-term vibration and harsh environment present in a wastewater system located under or adjacent to a roadway. Vibration from passing vehicles may cause false mechanical activation of level sensors and failure of sensitive float mechanisms. The harsh environment may also present debris and corrosive liquids that will deteriorate the operation of float systems. Additionally, mechanical float systems located in the space below a manhole cover can present an obstacle to maintenance personnel accessing the space.

[0007] Other known devices use electrical or optical probes to determine the liquid level. For example, self-heating thermistors or conductivity probes may be used. However, such systems using probes may be sensitive to humidity, moisture, changing temperatures, and varying voltage levels in the sensing circuit, all of which may produce erroneous results and subject the probes to wear. Also, contamination of the probes may adversely affect their performance. The probes and their associated circuitry may be adjusted to improve performance, but making the adjustments may be inconvenient and expensive.

[0008] A power supply line for supplying power to electronic sensors and communication of high liquid levels may be difficult and expensive to install for sensors located in existing roadways or remote areas. Batteries charged by solar cells offer a solution in some applications; however, solar cells may not be a viable option for a sensor located within some systems, for example, in a wastewater system located under a roadway.

[0009] Communication of a high liquid level to a central control or dispatch location presents an additional problem. Dedicated hard wiring or proprietary radio devices are generally cost prohibitive, may require excessive transmitter power, and tie municipalities to sole service providers.

[0010] What is needed is a liquid level sensor which reliably operates without the need for adjustment or external power. Also needed is a liquid level sensor which minimizes operating problems associated with contamination and mechanical wear. A further need exists for liquid level sensing which minimizes inaccuracies associated with varying temperatures.

[0011] What also is needed is a monitoring system that is cost effective, easily installed, and does not require a dedicated communications network.

SUMMARY OF THE INVENTION

[0012] The present invention provides a liquid level monitoring system for detecting high liquid levels in a wastewater handling system. The liquid level sensor system includes wireless sensor modules disposed in the wastewater handling system, a wireless network, a processing system, and notification messages.

[0013] Individual sensor modules may be located at various points in the wastewater handling system, for example, at access openings such as those provided by manhole covers. Each sensor module monitors the liquid level in the space below the module and, upon detection of a high liquid level, transmits an event message to the wireless network, which routes the event message to the processing system. In the exemplary embodiment, the processing system includes a database for correlating event messages with the originating sensor's location and segment of the wastewater handling system. Additionally, the processing system may produce and route a notification message, pertaining to the event, to a notification recipient, for example, maintenance dispatch personnel.

[0014] The exemplary embodiment of the wireless sensor module includes a capacitive probe, a capacitive sensing alarm circuit, and a wireless communication device. Capacitive sensing solves many of the related art's environmental sensitivity and mechanical reliability problems. Advantageously, the sensor module may be battery powered so that external electric power is not required. Thus, the sensor module can be easily mounted in locations where solar or electric power is not available, for example, on the interior surface of a manhole cover supporting ring such that the capacitive probe depends downward into the space below the manhole cover.

[0015] In the event the capacitive probe becomes submerged in liquid, the capacitive sensing alarm circuit detects the high liquid level and activates the wireless communication device, sending a sensor identifier and high liquid event message to the processing system via the wireless network.

[0016] The wireless communication device includes a processor and software for receiving inputs from the alarm circuit, monitoring events and for producing event messages and an antenna for transmitting event messages to the wireless network.

[0017] For sensor locations where the antenna can be mounted without regard to vehicular or other traffic, a conventional dipole antenna may be mounted on or adjacent to the manhole cover, a nearby pole, or another nearby installation location. For sensors mounted under a manhole cover located in a roadway, possible antenna configurations include, for example, a roadway-embedded loop antenna, an antenna embedded in a composite manhole cover, a relatively flat antenna mounted on top of the manhole cover, or a dipole antenna located adjacent the roadway.

[0018] Advantageously, the wireless network can be a preexisting terrestrial or satellite wireless network, for example, a cellular network. The wireless network receives event messages from the sensor module and retransmits them to the processing system via a communications network such as the Internet.

[0019] The processing system includes a database of sensor identifiers and the installed location of each sensor. The installed location may be registered in the database by using a WAP device, such as a cellular phone, which is held by the installer at the location of the sensor module, is able to send data to the database, and is able to determine and provide GPS coordinates or other location data. Thus, an event message received by the processing system can be correlated using the sensor identifier with the location of the high water or other detected event in the wastewater handling system. The processing system may provide a status and location report of events as well as a map indicating event locations and travel directions to the event location. The processing system may also provide this and other desirable data to the notification recipient in the form of a web page, e-mail, or other communication transmission.

[0020] One advantage of the liquid level monitoring system is that the capacitive probe arrangement is not as sensitive to vibration, debris, and other harsh environmental factors, as are mechanical devices. Another advantage of the present manhole cover liquid level sensor is that it has a low power state so that an external power source is not required and batteries only need to be replaced after a period of years or after transmission of an event message. Another advantage of the present system is that existing wireless network providers, the Internet, or other existing communications networks can be utilized for establishing communication between remotely located sensor modules, the processing system, and notification recipients.

[0021] In one form, the present invention provides a liquid level monitoring system for a wastewater or other liquid handling system, including a battery-powered sensor module capable of detecting liquid handling system events, the sensor module being associated with a segment of the liquid handling system, the sensor module including a wireless communication device having a processor and associated software enabling the communication device to detect events and determine event messages relating to at least one of liquid level and sensor module status, the communication device capable of transmitting the event messages; and a processing system receiving the event messages and producing and routing a notification message, the notification message including at least one of event location, identification of the segment, and event status.

[0022] In another form thereof, the present invention provides a battery-powered sensor module including a probe, a circuit having a detector connected to the probe and capable of detecting a high liquid level on the probe, and a wireless communication device connected to the alarm circuit and having a processor and associated software enabling the communication device to determine event messages based on output of the circuit, the event messages relating to at least one of liquid level and sensor module status, the communication device capable of transmitting the event messages.

[0023] In yet another form thereof, the present invention provides a method of monitoring the liquid level of a wastewater handling system, including the steps of installing a sensor module in a segment of the wastewater handling systems, the sensor module having a wireless communication device and a sensor circuit, registering the sensor module location and identification code in a processing system, activating power to the communication device upon the sensor circuit detecting a first high liquid level, and transmitting an event message including the sensor module identification code from the communication device to the processing system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

[0025] Fig. 1 is a block diagram of the manhole cover liquid level monitoring system in accordance with the present invention;

[0026] Figs. 2A and 2B are block schematic diagrams of a sensor module of the liquid level system of Fig. 1;

[0027] Fig. 3 is a perspective view of an uninstalled sensor module of Fig. 2;

[0028] Fig. 4A is a top view of a manhole cover and supporting ring showing the liquid level sensor module of Fig. 2 mounted to the supporting ring;

[0029] Fig. 4B is a side view of the manhole cover and supporting ring of Fig. 4a;

[0030] Figs. 5A and 5B are a schematic diagram of a portion of the liquid level sensor module of Fig. 2;

[0031] Fig. 6 is a flowchart of the installation and registration process of the sensor module of Fig. 2 with the liquid level system of Fig. 1;

[0032] Figs. 7A and 7B are a flowchart of the operation of the wireless communications device of the sensor module of Fig. 2;

[0033] Fig. 8 is a plan view of a web-based status report of the manhole cover liquid level monitoring system of Fig. 1;

[0034] Fig. 9 is a plan view of a web-based status history report of the sensor module of Fig. 2;

[0035] Fig. 10 is a plan view of a web-based location map of the sensor module of Fig. 2; and

[0036] Figure 11 is a plan view of a web-based travel directions report for the sensor module of Fig. 2.

[0037] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplary embodiment of the invention illustrated herein is not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION

[0038] The embodiments disclosed below are not intended to be exhaustive or limit the invention to the precise forms disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings.

[0039] The present invention comprises a manhole cover liquid level monitoring system for wireless monitoring of the liquid level under manhole covers in a wastewater, storm water, or other material handling system. As depicted in Fig. 1, the exemplary embodiment of monitoring system **20** is capable of monitoring liquid levels in wastewater handling system 31 and generally includes liquid level sensor module **22** wireless access protocol (WAP) device **24**, communications network **26**, and processing system **28**. Individual sensor modules **22** may be located at various segments in wastewater handling system **31**, for example, at manhole cover access point **32**. In the event sensor module **22** detects a high liquid level or other monitored event, event message **34** is transmitted by sensor module **22** to existing communications network **26**.

[0040] Communications network **26** may include a receiving system, for example, terrestrial antenna **36** or satellite **38** and satellite receiver **40**, network path **42**, and network operations center **44**. Event message **34** is relayed by network operations center **44** of communications network **26** to Internet **46** or another communications network or connection that transmits event message **34** to processing system **28**. Processing system **28** processes event message **34** and accesses database **30**, which matches event message **34** with an event location, to produce notification message **30**. Notification message **30** relates to the sensed event and may be transmitted through Internet **46** or another communications network or connection to notification recipient **48**, such as a maintenance dispatch personnel.

[0041] Processing system **28** includes hardware and software for processing event messages **34** and producing notification messages **30.** Event message receiver **28a** receives event messages 34 communicated by sensor module **22**. Sensor module identifier **28b** identifies the particular sensor module **22** which transmitted event message **34**, for example based on an identifying code included in event message **34**. Event locator **28c** determines the location of sensor module **22** including the segment of waste water handling system **31** to which event message **34** pertains. For example, event locator **28c** may use the sensor module identifying code and data base **29** to determine the installed location in segment. Notification message generator **28d** generates notification message **30** based upon received event message **34**, the determined event location, and other pre-determined parameters as programmed and specified by data base **29**.

[0042] Referring now to Figs. 2A and 3, an exemplary embodiment of sensor module **22** includes enclosure **50** and cover **52** for sealably enclosing circuit board **54** and battery **56**. Circuit board **54** includes capacitive sensing alarm circuit **60** and wireless communication device **58**. Alternatively, alarm circuit **60** may be separately disposed from wireless communications device 58, for example, communication device **58** may be disposed on a separate circuit board or in a separate enclosure. Communication device **58** may be, for example, a wireless modem capable of transmitting event message **34** upon alarm circuit **60** detecting a high liquid level or other event in wastewater handling system **31**.

[0043] Extending from circuit board **54** and sealably protruding through enclosure **50** are ground wire **62**, sensor wire **64**, and antenna cable **66** (Fig. 2A). Ground wire **62** and sensor wire **64** may include weight **68** on the distant end to support extension of the wires **62** and **64** below sensor module **22**. In the exemplary embodiment, ground wire **62** includes at least one portion of exposed wire **63** to provide reliable grounding with the liquid being sensed. Sensor wire **64** is an element of capacitive probe **70** (Fig. 5) and sensor wire **64** is, therefore, fully insulated by dielectric **72**. For example, sensor wire **64** may be an insulated wire which also has its distant end sealably and dielectrically encapsulated.

[0044] Ground wire **62** and/or sensor wire **64** may also comprise other configurations. For example, ground wire **62** and sensor wire **64** may comprise circuit traces disposed on a portion of circuit board **54** which sealably protrudes through enclosure **50** and cover **52**. Similar to the exemplary embodiment above, the circuit trace defining sensor wire **64** is sealed from the liquid being detected, while the circuit trace defining ground wire **62** is exposed. Ground wire **62** and sensor wire **64** may also be an insulated two conductor cable, having portion **63** of ground wire **62** exposed, while sensor wire **64** is encapsulated, for example, as shown in Fig. 3. Weight **68** may seal the distal end of sensor wire **64**. Weight **68** may also have a conductive portion in contact with ground wire **62**.

[0045] Exemplary sensor module **22** is sealed by enclosure **50** and cover **52** and may be otherwise designed to resist exposure of circuit elements to liquid and the surrounding elements in order to satisfy hazardous location standards for electronic devices. Such standards may include, for example, those developed by Underwriters Laboratories, Inc.

[0046] Referring now to Figs. 4A and 4B, the exemplary embodiment of monitoring system **20** includes sensor module **22** mounted, for example, by fasteners **80**, to interior wall **74** of manhole supporting ring **76**. Thus, sensor module **22** is located below manhole cover **78** and is positioned so that ground wire **62** and sensor wire **64** may extend downward into the opening into wastewater handling system **31** below manhole cover **78**. Depending on the desired distance below manhole cover **78** at which a high liquid level is desired to be sensed, ground wire **62** and sensor wire **64** may extend a few inches below sensor module **22** or many feet. Alternatively, sensor module **22** may be located at another portion of wastewater handling system **31**, for example, a drain, vent, or clean-out element.

[0047] Wireless communication device **58** (Fig. 2A) transmits event messages via antenna cable **66** and antenna **82**. Though many antenna configurations are possible, the exemplary embodiment may include one of several alternative antennas, as shown in Fig. 4B. Manhole cover mounted antenna **82a** extends only slightly above manhole cover **78** and endures loads applied by vehicular or other traffic. Antenna **82a** includes antenna cable connector **84** extending through clearance hole **86** defined through manhole cover **78**. Such a cover mounted antenna is, for example, Model #ANT-ML860 available from Optimum Instruments, Inc., Edmonton, AB, Canada.

[0048] Also able to withstand vehicular traffic, road loop antenna **82b**, such as is available from AXCESS, Inc., Carrollton, Texas, may be buried in roadway **86** adjacent to manhole cover supporting ring **76**. Also capable of enduring vehicular traffic, manhole cover **78** can be replaced with a composite manhole cover that includes embedded antenna **82c**, such as those available from Elan Industries, Hickory Hills, Illinois. Additionally, if manhole cover **78** is in a remote location or if vehicular traffic is not a concern, a conventional dipole antenna **82d** mounted adjacent manhole cover **78** or on pole **88** may be used to support transmission of event message **34**. In any event, antenna **82** is selected for compatibility with communications network **26** and communication device **58**.

[0049] In the exemplary embodiment, electric power for wireless communication device **58** and capacitive sensing alarm circuit **60** is provided by battery **56**; however, other sources, for example solar power, could be used. Alarm circuit **60** has a low power requirement and wireless communication device **20** is typically unpowered until activated by alarm circuit **60**. Therefore, alkaline, lithium, or other long-lasting batteries can provide sufficient power to support the operation of sensor module **22** for several years.

[0050] Referring now to Fig. 2B, in the exemplary embodiment, wireless communication device **58** includes communication receiver/transmitter **58a**, which is coupled to antenna cable **66** and antenna **82**, processor/software **59**, and data controller **58b**, which receives inputs and modem supply Vcc for powering communication device **58** from data interface **60d** of capacitive sensing alarm circuit **60**. Capacitive sensing alarm circuit **60** may include liquid level sensor **60a**, which is coupled to probe **70**, still alive timer **94**, battery low sensor **96**, built-in test (BIT) device **60b**, communication device power latch and driver **60c**, and data interface **60e**.

[0051] Liquid level sensor **60a** is capable of detecting a high and low liquid levels on probe **70**, and producing an output signal which is receivable by power latch and driver **60c** and data interface **60d**. Still alive timer **94** produces an output signal upon a pre-determined timer interval, the output signal receivable by latch and driver **60c** and data interface **60d**. Battery low sensor **96** monitors battery **56** and produces an output signal upon battery power dropping below a pre-determined level. The output signal from battery low sensor **96** is receivable by latch and driver **60c**. BIT device **60b** is capable of receiving an operator signal and initiating a BIT test. BIT device **60b** produces an output signal receivable by power latch and driver **60c** and data interface **60d**. Communication device power latch and driver **60c** and data interface **60d**. Communication device power latch and driver **60c** produces modem supply Vcc for powering communication device **58** upon latch and driver **60c** receiving an input signal from liquid level sensor **60a**, still alive timer **94**, battery low sensor **96**, or BIT device **60b**. Latch and driver **60c** driven modem supply Vcc continues for a pre-determined interval upon termination of the input signals.

[0052] Processor and software **59** receive signals from alarm circuit **60** via data interface **60d** and data controller **58b**. Although in the exemplary embodiment, the various aspects of processor and software **59** are implemented by software, the aspects may also be implemented by hardware or a combination of hardware and software. Event alarm monitor **59a** is activated upon receiving a signal from alarm circuit **60**. Upon receiving the signal, event alarm monitor **59a** activates power/wake/sleep control **59b** to wake communication device **58** from a low power state. Power/wake/sleep control **59b** also monitors modem supply Vcc for a low battery condition.

[0053] Event message generator **59c** generates event message **34** depending upon pre-determined programming, parameters stored in memory **59f**, input signals received from alarm circuit **60** and processing system **28**, via communication receiver transmitter **58a**, and input from power/wake/sleep control **59b**. Additionally, event message generator **59c** may incorporate an identifying code for sensor module **22**, which is received from identifying code generator **59d**. Timer **59e** may be used for waking wireless communication device **58d** on a pre-determined periodic interval in order to perform a pre-determined function, for example, transmitting a pre-determined event message. Power/wake/sleep control **59b** may also place communication's device **58** in a low power sleep state upon expiration of a pre-determined timer interval received from timer **59e**, the timer interval being reset each time an input signal state received by data controller **58b** changes.

[0054] Referring now to Figs. 5A and 5B, exemplary alarm circuit **60** includes capacitive probe **70** and charge transfer sensor **U14** for detecting the liquid level rising below sensor module **22**. Capacitive probe **70** includes sensor wire **64**, reference capacitor **C2**, and resistor **R2**. Capacitor **C2** and resistor **R2** values are selected based on the requirements of sensor **U14** and the characteristics of sensor wire **64** and dielectric **72**, including wire gauge and length, and dielectric thickness.

[0055] Dielectric **72** sealably encases sensor wire **64** so that a charge may develop between sensor wire **64** and the liquid being detected, which is in electrical contact with sensor ground **62**. Sensor wire **64** receives and transmits a charge that varies depending on the length of sensor wire **64** that is covered by liquid. Thus, by charging probe **70** to a fixed potential, then transferring and measuring the charge held by probe **70**, charge transfer sensor **U14** can accurately detect the liquid level, including two different high liquid levels and a low liquid level.

[0056] Probe **70** is charged by battery **90** through resistor **R1**, which is selected to reduce voltage transients, and through electrostatic discharge protection network **92**, which includes diode pair **D1** and capacitor **C1**, which are connected to sensor ground wire **62**. Sensor wire **64** is also connected through resistor **R2** to sense input 2 at pin 7 of sensor **U14**. Reference capacitor **C2** is connected across sense input 2 at pin 7 and sense input 1 at pin 6 of sensor **U14**.

[0057] A slosh/sensitivity filter of sensor **U14** can be selected by connecting pin 2 to supply V_{CC} of battery **90** at pins 1 and 2 of connector **J2**. Alternatively, connecting pin 2 of connector **J2** to ground at pin 3 of connector **J2** deselects the slosh/sensitivity filter sensor **U14**. The output polarity of sensor **U14** is selected by connecting pin 2 of connector **J3** to battery supply V_{CC} at pin 1 of connector **J3** for active high output, or to pin 3 of connector **J3** for active low output. Output active high is selected for the exemplary embodiment. Thus, output 1 at pin 2 of sensor **U14** is driven to a high level when a predetermined first high liquid level is detected on sensor wire **64**. Capacitor **C6** connected to output 1 of sensor **U14** eliminates a diagnostic pulse output that is characteristic of charge transfer sensor **U14** used in the exemplary embodiment.

[0058] In the exemplary embodiment, sensor **U14** is configured to provide output 1 upon detecting a predetermined first high liquid level on probe **70**. Referring to Fig. 5B, the resistor network including **R11** and **R12** provides inactive pull-down for active high output 1 of sensor **U14**, and the junction of resistors **R11** and **R12** provides an output status line to pin 1 of connector **J1**, which is monitored by communication device **58**.

[0059] A high state of output 1 of sensor **U14** provides a supply current to the gate of MOSFET **Q4A**. Additionally, output 1 of sensor **U14** charges timer circuit capacitor **C4** and resistor **R3**, thus latching **Q4A** on, irregardless of the subsequent state of output 1, for a delay period of time determined by the values of capacitor **C4** and resistor **R3**. MOSFET **Q4A** provides a drain to ground for the gate of MOSFET **Q5A**. Thus, normally high resistor **R10** connected from supply V_{CC} to the gate of MOSFET **Q5A** is pulled to ground, switching supply V_{CC} through MOSFET **Q5A** to connector **J1** pins 7 and 8 and to the resistor network consisting of resistors **R7** and **R8**. Connector **J1** pins 7 and 8 are also connected to modem power supply V_{CC} for communication device **58**, thus providing power so that communication device **58** may detect inputs from alarm circuit **60** and transmit event message **34**. Voltage divider **R7** and **R8** provide 3.3 volts to pin 10 of **J1**, switching communication device **58** from a low-power "sleep" state to a high-power transmitting state. Pins 9 and 18 of **J1** provide the circuit ground to communication device **58**.

[0060] Output 2 at pin 3 of sensor **U14** may be coupled through resistor **R13** and across resistor **R14** and capacitor **C7** to pin 2 of connector **J1**, which is also monitored by communication device **58**. Output 2 may be configured to provide an active high output upon sensor **U14** detecting a predetermined second high liquid level on probe **70**. The second high liquid level is selected to represent a higher liquid level in wastewater handling system **31** than the first high liquid level indicated by output 1 of sensor **U14**.

[0061] Upon the liquid in which probe **70** is immersed falling below the first high liquid level, output 1 of sensor **U14** returns to a low state and timer delay capacitor **C4** is discharged. After capacitor **C4** is discharged through resistor **R3**, MOSFET **Q4A** no longer provides a drain to ground and the gate for MOSFET **Q5A** returns to source V_{CC} turning off MOSFET **Q5A** and thus terminating the voltage supply V_{CC} to communication device **58**. However, the timer delay is of sufficient length for communication device **58** to detect and transmit a message regarding the low liquid level as indicated by both output 1 and 2 of sensor **U14** returning to a low state.

[0062] Capacitive sensing alarm circuit **60** also provides a sensor module built-in test (BIT) function and event. Upon pressing switch **SW1**, two circuits are energized--MOSFET **Q4A** and MOSFET **Q5A** as previously described, and MOSFET **Q4B** and MOSFET **Q5B**. In order to protect output 1 at pin 2 of sensor **U14** from a reverse current when switch **SW1** provides battery supply V_{CC} to MOSFET **Q4A**, the Schottky diode **D2** anode is connected to output 1, pin 2 of sensor **U14** and the cathode of diode **D2** to the gate of MOSFET **Q4A**, which is supplied with battery supply V_{CC} upon test switch **SW1** being engaged. Thus, activating test switch **SW1** provides a signal to the same communication device **58** connector pins (**7**, **8**) as does sensing a high liquid level on sensor wire **33** and also provides a BIT signal to connector pin **3** of communication device **58**.

[0063] The BIT signal is provided by MOSFET **Q4B** and latch timer components capacitor **C5** and **R4**, and MOSFET **Q5B** and resistor **R9** in much the same fashion as a high liquid level signal from output 1 of **U14** is provided by MOSFET **Q4A** and **Q5A**. MOSFET Q**5B** provides modem supply V_{CC} to communication device **58**, through the resistor network comprised of resistors **R5** and **R6**, to pull the BIT signal high at pin 3 of connector **J1**. Upon disengagement of test switch **SW1**, MOSFET **Q4A** and **Q5A** will turn off in accordance with the respective time delay components, and subsequently turn off MOSFET **Q5A** and **Q5B**, returning communication device **58** to a no power mode.

[0064] Capacitive sensing alarm circuit **60** also provides inputs to wireless communication device **58** relating to the voltage level of battery **56**. Still-alive timer **94** monitors battery **56**, for example by periodically measuring battery V_{CC}. If the available supply V_{CC} is sufficient for operation of alarm circuit **60** and communication device **58**, still-alive timer **94** will drive MOSFET **Q4A** and **Q5A**, through diode **D3**. The signal is provided through resistor **R13** and across capacitor **C7** and resistor **R14** to pin 4 of connector **J1**, thus providing modem supply V_{CC} to communications device **58** and indicating that sensor module **22** is still functional.

[0065] Battery low sensor **96** monitors battery **56**. If battery supply V_{CC} drops below a predetermined level which indicates that battery **56** power will soon be incapable of monitoring the liquid level on probe **70** or of transmitting messages to processing system **28**, activation of the output of battery low sensor **96** occurs. Battery low sensor drives MOSFET **Q4A** and **Q5A** through diode **D4**. Communication device **58** is thereby powered by modem supply V_{CC} and is then able to monitor the level of modem supply Vcc, which reflects battery **56** charge, and to accordingly transmit a message to processing system **28**.

[0066] Still-alive timer **94** is powered by battery **56** and, upon a predetermined timer interval, produces an output signal indicating that sensor module **22** is still sufficiently powered and remains operational. Activation of the output of still-alive **94** drives MOSFET **Q4A** and **Q45** through diode **D3**, and pin **4** of connector **J1** is driven high through resistor **R13** and across resistor **R14** and capacitor **C7**. Communication device **58** is thereby powered by modem supply V_{CC} and receives an indication on pin **4** that the periodic still-alive timer interval has been reached.

[0067] Various devisable portions of capacitive alarm sensing circuit **60** may be selectively included or excluded as desired for individual embodiments of sensor module **22**. For example, an embodiment may exclude still-alive timer **94** and associated components. Additionally, other monitoring circuits may be included in an embodiment of sensor module **22**, for example, a motion detector or other environmental sensor.

[0068] In the exemplary embodiment, wireless communication device **58** is advantageously an RF transceiver compatible with existing wireless network **26**, which may be, for example, a cellular communications network. Additionally, communications device **58** includes processor and software application **59** for easy configuration and modification, including establishing various event messages and loading a sensor identifier code to be transmitted with event message **34**. An exemplary wireless communication devices **58** are Part No. RIM 902M, available from Research In Motion, Waterloo, ON, Canada, and the devices disclosed by U.S. Patents No. 5,619,531, issued April 8, 1997; No. 5,727,020, issued March 10, 1998; No. 5,764,693, issued June 9, 1998; and No. 5,917,854, issued June 29, 1999; all of which are titled "Wireless Radio Modem with Minimal Interdevice RF Interference," the disclosures of which are hereby incorporated herein by reference.

[0069] The method illustrated by the flowchart of Fig. 6 provides installation and registration of sensor module **22** with processing system **28**, shown in Fig. 1. The method begins in step 150. In step 152, sensor module **22** and antenna **82** are physically installed at the desired location of wastewater handling system **31**. In step 154, communication is initiated between WAP device **24** and system processor **154**. The communication may be provided through existing communication network **26** and internet **46**, for example, by accessing processing system **28** via web-enabled WAP device **24**.

[0070] In step 156, once communication with processing system **28** is established, the installer selects registration of sensor module **22** in processing system **28** via WAP device **24**. In step 158, WAP device **24** transmits GPS coordinates or other location information to system processor **28**. For example, WAP device 24 may be GPS enabled and transmit the current GPS coordinates detected by WAP device **24**, which is presently located in close proximity to installed sensor module **22**.

[0071] In step 160, the installer initiates a built-in test (BIT) of sensor module **22** by pressing pushbutton switch SW1. In step 162, sensor module **22** transmits registration information including an identifying code, for example a serial number, to system processor **28**. In step 164, system processor **28** receives and processes the registration information from sensor module **22** and transmits confirming information, such as serial number and location, to WAP device **24**. In step 166, the installer confirms the registration of sensor module **22** with processing system **28** via WAP device **24**.

[0072] In step 168, sensor module **22** is placed in a power-saving mode by powering down wireless communication device **58**. The power-saving mode may be selected by sensor module **22** receiving confirmation of registration from processing system **28**, or by the installer initiating a second BIT by pressing pushbutton SW1, or by another initiating event. In step 170, sensor module **22** begins liquid level monitoring and processing system **28** begins monitoring of communications from sensor module **22**. The installation procedure is complete in step 172.

[0073] Referring to Figs. 7A and 7B, the steps of the operation of wireless communications device **58** are illustrated by the flowchart. In the preferred embodiment, wireless communications device **28** is a wireless modem having processor and software **59**. At least a portion of the illustrated steps are implemented by processor and software **59** and may be loaded into communication device **58** via serial programming port **J4** (Fig. 5B) or by wireless transmission to communication device **58**. Pins **2** and **3** of connector **J4** provide transmit and receive and pin **16** of **J1** provides active low Request to Send and pin **19** of **J1** provides active low Data Terminal Ready for a serial connection with communication device **58**.

[0074] The operation of wireless communications device **58** begins in step 200 after sensor module **22** is registered with processing system **28**. In step 202, alarm circuit **60** determines whether to cut off power to device **58**. If so, step 204 is completed, else step 206 is completed. In step 204 device **58** is powered down to a no-power state. Advantageously, device **58** will remain in the no-power state until an event occurs that requires processing or a transmission of an event message to processing system **28**. In step 206, processor **59** determines whether device **58** should be powered up from a low power standby state to the high power state for determination of an event and transmission of a message, for example, upon data controller **58b** receiving modem supply Vcc from sensing circuit **60**. If inputs from sensing circuit **60** are detected and require an event message, then in step 210 device **58** will be powered up, else operation loops back to step 202.

[0075] In step 212, processor **59** determines whether input pin 1 of connector **J1** is active, indicating a first high liquid level is detected by alarm circuit **60**. If so, in step 214 processor **59** adds a first high liquid level event to event message **34**. In step 216, processor **59** determines whether input pin 2 of connector **J1** is active, indicating a second high liquid level has been detected by sensing circuit **60**. If so, in step 218 processor **59** adds a second high liquid level to the outgoing message. In step 220, processor **59** determines whether input pins 1 and 2 of connector **J1** are not active, indicating a low liquid level event has been detected by alarm circuit **60**. If so, in step 224, processor **59** adds a low liquid level event to event message **34**.

[0076] In step 226 (Fig. 7B), processor **59** determines whether input pin 3 is active indicating a built-in test has been initiated by pressing pushbutton SW1. If so, in step 228, a built-in test is completed by communication device **58**, else operation continues at step 232. In step 230, processor **59** adds a built-in test event to event message **34**.

[0077] In step 232, processor **59** determines whether a low voltage for battery **56** has been detected by power/wake/sleep control **59b**. If so, in step 234, processor **59** adds a battery-low event to event message **34**, else operation continues at step 236.

[0078] In step 236, processor **59** determines whether pin 4 is active indicating still-alive timer **94** has reached the next timer. If the interval has been reached, in step 238, processor **59** adds a still-alive event to event message **34**, else operation continues at step 240.

[0079] In step 240, communication device **58** transmits event message **34** to communications network **26**. In step 242, processor **59** returns communication device **58** to the low-power standby state. After step 242 is completed, operation loops to step 202 and the process is repeated.

[0080] Referring to Fig. 1, transmitted event message **34** is received by existing communications network **26**. The exemplary communications networks includes, by way of example, satellite **38** and satellite receiver **40**, or terrestrial antenna **36**, network path

42, and network operations center **44**. For example, the exemplary embodiment uses a Mobitex wireless network. Network operations center **44** of communications network **26** provides continuity with other communications networks, for example, Internet **46**. Thus, network operation center **44** forwards event message **34** through Internet **46** to processing system **28**. In order for communication device **58** to send event message **34** to processing system **28**, typical wireless modem communications events may occur. For example, processing systems **28** or communication network **26** may transmit a ready to receive message to communication device **58**.

[0081] Processing system **28** may be any type of data processor, for example, a Windows-based computer. Processing system **28** may also include database **29**. In the exemplary embodiment, database **29** is used to register installation locations of sensor modules **22**, indexing them by unique sensor identifiers and/or location. When event message **34** is received by processing system **28**, the sensor identifier contained in event message **34** may be used to retrieve the installed location of sensor module **22** which transmitted event message **34**. Processing system **28** also provides date and time stamping of events received in event messages **34**. Processing system **28** may also utilize database **29** to store or retrieve event history or other information regarding sensor module **22** or wastewater handling system **31**.

[0082] Processing system **28** may then provide a status and location report (Fig. 8) of sensor module **22**, an event history report (Fig. 9), a map (Fig. 10) indicating the event location and status, travel directions (Fig. 11) to the event location and other such information, useful for monitoring and correcting conditions of wastewater handling system **31**. Processing system **28** may provide this information in notification message **30** via a web page, as shown in Figs. 8-11, e-mail, page, or by any other form of communication transmission. Exemplary processing system **28** is available from Cloudberry Wireless Services of San Diego, California, and ArcLocation™ Solutions, ERSI of Redlands, California.

[0083] Recipient **48** of notification message **30** may be a municipal operation center, maintenance dispatch center, emergency management center, or the like, who monitor and/or respond to events of wastewater handling system **31**.

[0084] Processing system **28** or communication device **58** may also provide other tasks based on the events detected by sensor module **22**. For example, by monitoring the elapsed time between detecting a first high liquid level and detecting the initiation or terminating of a second high liquid level or low liquid level, the rate of change of the liquid level in wastewater handling system **31** may be determined, or predicted time for flooding of manhole cover **32** may be predicted. Additionally, recording of the use of WAP device **24** at sensor module **22** or initiation of a built-in test can be used to document physical inspection of an event in accordance with Environmental Protection Agency regulations or other such compliance requirements.

[0085] While the exemplary embodiment provides remote monitoring of wastewater handling system **31**, sensor module **22** and other elements of system **20** may be used for remote monitoring of other systems, locations, or events. For example, sensor module **22** may be installed in a basement or in an industrial location requiring liquid level or other such environmental monitoring.

[0086] The values of the circuit elements shown in Figs. 5A and 5B are given below in Table 1:

TABLE 1

ELEMENT	VALUE
R1	1K
R2	50K
R3	1M
R4	1M
R5	12K
R6	33K
R7	12K
R8	33K
R9	1M
R10	1M
R11	12K
R12	33K
R13	12K
R14	33K
R15	12K
R16	33K
C1	10μ*f*
C2	100n*f*
C3	100n*f*
C4	47μ*f*
C5	47μ*f*
C6	100p*f*
C7	100 p*f*
C8	100 p*f*
C9	100 p*f*
U14	QT114 Quantum Research Group

ELEMENT	VALUE
D1	BAV99/SOT
D2	Schottky Diode
D3	Schottky Diode
D4	Schottky Diode
Q4A, Q4B	MOSFET ZXMD63N02XTA
Q5A, Q5B	MOSFET ZXMD65P02N8TA

[0087] The description of the circuit lines at connector **J1**, which couples capacitive sensing alarm circuit **60** to wireless communications device **58,** are given below in Table 2.

TABLE 2

PIN #	DESCRIPTION
1,2,3,4	Bidirectional I/O lines
7, 8	Power
9	Ground
10	Turn Wireless Tx/Rx On
16	~Request To Send
18	Ground
19	~Data Terminal Ready
20	Transmit
21	Receive

[0088] While this invention has been described as having exemplary embodiments and scenarios, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations or the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.